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With the author's
kind regards.

C. Lovell Evans.

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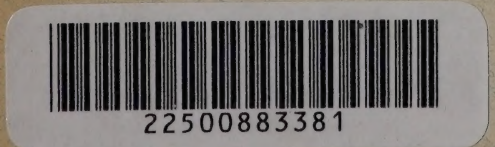

Extrait du *Livre jubilaire* du Professeur Ch. Richet,
1912, page 471.

THE PRODUCTION

OF HEAT IN DECEREBRATE RIGIDITY

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Considerable evidence has been brought forward during the last few years to show that muscle related to the smooth or involuntary muscle of the vertebrate is able to maintain itself in a state of tonic contraction without any apparent consumption of energy. It becomes, as it were, hooked up or supported in some way in a shortened form, so that in this new state the natural length of the muscle, or the length assumed by it when not excited to action, is a shorter one than it was in the previous state.

The experimente of Parnas[1], who finds that the tonic contraction of the adductor muscles of various species of bivalve Molluscs, which resists powerful efforts to open the shell, is not associated with any greater metabolism than when relaxed and the shells widely separated. In warm-blooded animals, it will be remembered that Mosso and Pellacani[2] showed that the bladder is capable of wide changes in capacity without corresponding changes in internal pressure or tension in the muscular coat.

Other instances might be given, but the reader will find a complete account in the papers by Bethe[3] and by Roaf[4].

The condition assumed by certain groups of voluntary, skeletal,

1. Parnas : *Arch. f. d. ges. Physiol.*, t. CXXXIV, p. 441, 1910.
2. Mosso and Pellacani : *Arch. ital. de Biolog.*, t. I, p. 97 and 291, 1882.
3. Bethe : *Arch. f. d. ges. Physiol.*, t. CXLII, p. 291, 1911.
4. Roaf : *Quart. Journ. Exp. Physiol.*, t. V, p. 31, 1912.

muscles in the decerberate Mammal, described by Sherrington[1] as that of "decerebrate rigidity", presents obvious similarity to that referred to above in the case of smooth muscle. Accordingly, Roaf[2], at the suggestion of Sherrington, undertook the estimation of the energy required to maintain the muscles in this state of tonic contraction. He found that the output of carbon dioxide was no greater during decerebrate rigidity than when the muscles were completely relaxed by administration of curare.

The experiments with which the present paper is concerned were made in order to see whether any light would be thrown on the question by the determination of the amount of production of heat in muscles in the condition referred to. The temperature of the muscle was taken to indicate approximately the degree of this production, although it is plain that calorimetric measurements are necessary to obtain quantitative values.

The muscles used were the vasto-crureus in the hind-limb of the cat and the triceps in the forelimb. The former muscle was chosen because, as Sherrington has shown[3], its tonus can be increased by exciting the central end of the sciatic nerve of the opposite side and decreased or inhibited by exciting the central end of some sensory nerve of the same side. The triceps brachii served better for the investigation of the prolonged tonus, since, under the conditions of my experiments, it was maintained in this muscle to a strong degree for a longer time than in the vasto-crureus.

Decerebration was performed in Sherrington's method under deep chloroform anaesthesia. After the operation, administration of anaesthetic was stopped entirely.

The degree of tonus was judged by supporting the humerus or femur in such a way that the distal part of the limb was free to move in front of a divided scale.

The temperature of the muscle was determined by inserting into it a thermo-electric junction of nickel and iron. The whole limb was then wrapped in cotton-wool. A second similar nickel-iron junction in the opposite direction was immersed in water in a vacuum-jacketed vessel, which also contained a Beckmann thermometer graduated in hundredths of a degree. The temperature in this vessel was raised by

1. Sherrington : *Journ. of Physiol.*, v. XXII, p. 319, 1898.
2. Roaf : *Proc. Roy. Soc.*, v. LXXXIII, p. 483, 1910.
3. Sherrington : *Integ. Action of the Nervous System.*, p. 83-113, 1906.

means of a coil of wire through which an electric current was passed until the galvanometer showed no deflection, at this point the temperature of the two junctions would be the same. This temperature was then kept practically constant by regulation of the current, a very small current being sufficient to balance loss through the walls of the vessel. The changes in temperature of the muscle were then indicated by deflections of the galvanometer, controlled by allowing for any slight change of temperature in the vacuum vessel by reading simultaneously the thermometer therein. The boiling tube of the Beckmann boiling point apparatus for electric heating was found convenient for the purpose[1]. The junctions of the two iron wires with the copper leads to the galvanometer were immersed in water side by side. The galvanometer used was a Kelvin instrument of five ohms resistance. The sensibility of the arrangement as a whole was made intentionally rather low, because otherwise it would have been too unsteady. In most experiments, one degree centigrade difference of temperature between the two junctions gave a deflection of 380 divisions of the galvanometer scale.

It is to be remembered that heat produced in a muscle with the blood current flowing will be conducted away rapidly; so that when, for example, the nerve is excited for a short time, the temperature, after rising, returns quickly to its previous state when the stimulus ceases. The actual rise of temperature observed, moreover, will clearly be less than would be seen in the absence of the blood circulation. Another circumstance to be taken into account is that, when contraction is accompanied by the production of carbonic or lactic acids, the arterioles will be dilated and hence the blood current will be accelerated. This blood will in all probability have a higher temperature than that of the resting muscle and hence the heat formed in contractions associated with metabolism of muscle substance will be favoured in comparison with those contractions, if such exist, in which no energy change occurs.

Results of experiments. When the act of decerebration was performed in so great a depth of anaesthesia that no muscular contractions were caused, as it ought to be, it was found that there was no immediate change in the temperature of the observed muscle. But, as the rigidity gradually developed the temperature rose slightly,

1. Beckmann : *Zeit. f. physik. Chem.*, t. LXXVIII, p. 726, 1911.

pari passu with the change in posture of the limb. In cases of full rigidity, however, the rise never amounted to more than 0°,2 C., a galvanometer deflection of 90 to 100 divisions of the scale; in the majority of cases, the amount was less, only 0°,05 to 0°,08. If the nerve to the muscle was excited by the direct application of induced shocks, a very short series of these was sufficient to produce deflections of 330 to 400 scale divisions, indicating a rise of temperature of about a degree.

It was usually found that, if the animal were left untouched for some minutes, the muscular rigidity disappeared, but could be brought on again by any kind of sensory stimulation of the limb of the opposite side, as described by Sherrington. This reappearance of the decerebrate rigidity was accompanied by a rise of temperature of about 0°,1 ; the rise was maintained for some minutes, so that it could not have been merely due to the initial act of shortening of the muscle, but must have been continuously produced during the steady tonus. In fact, it continued for some minutes while the state of rigidity lasted, slowly disappearing as the limb fell back to its relaxed position. The movement of the spot of light, indeed, followed that of the limb.

Sherrington[1] found that, in the decerebrate state, if a relaxed limb were raised by hand to the position it would assume in tonus, a tonic contraction, the "shortening reaction", was induced reflexly, so that the limb remained more or less in the position to which it had been raised. If this is done while the temperature of the muscle is observed, I have sometimes noticed a slight rise of temperature, amounting to 0°,05 or 20 scale divisions, small but unmistakeable. At other times the rise was too small to measure, although the muscle obviously went into tonus.

If the second thermo-electric junction were placed in the corresponding muscle of the opposite side, whose nerves had been divided, instead of in the vacuum vessel, it was noted that the temperature of the normal side in tonus was slightly higher than that on which the nerves were cut.

Convulsive contractions produced by strychnine were always accompanied by a large rise of temperature, the spot of light passing rapidly off the scale.

1. Sherrington : *Quart. Journ. Exp. Physiol.*, t. II, p. 109, 1909.

Mr. Lovatt Evans kindly allows me to refer to some experiments of his, not yet published, in which he found evidence that the abolition of decerebrate rigidity by curare was accompanied by reduction in the output of carbon dioxide, so that his results do not confirm those of Roaf. Whether this difference was less than would have been the case if the muscles had been in the ordinary form of contraction, in place of the decerebrate tone, it is impossible to state.

There are two points in respect to the tonus of the molluscan adductor muscle which are not yet quite clear. The decerebrate rigidity of the cat is dependent on the connection of the muscles with the central nervous system and it is important to know whether the state of tone of the adductor muscle is maintained by continous reflex impulses from nerve centres or otherwise. Further, it is possible that the shortened state is not actually associated with increased tension. If this were so, the act of stretching the muscle, when attempts are made to open the shell, may be the cause of reflex contraction of the usual type.

The conclusion that I have been led to by the experiments above described is of somewhat unsatisfactory nature. A certain amount of heat seems undoubtedly to be produced in decerebrate tone; although it is very small compared with that formed in ordinary tetanic contraction. There is some evidence, then, that there may be two kinds of contractile process in muscle fibre.

Paris. — L. Maretheux, imprimeur, 1, rue Cassette.

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Heart in Decerebrate Rigidity

Baglis.